AN ABRUPT CHANGE IN STRATOSPHERIC CIRCULATION BEGINNING IN MID-JANUARY 1958

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1. INTRODUCTION

Observational studies referred to by Kochanski and Wasko [1] show that winds at the 25-mb. constant pressure surface (altitude approximately 82,000 ft. or 25 km.) north of 30° N. latitude are generally westerly during the winter and easterly during the summer. The change from the summer regime begins in early autumn with the appearance of westerly winds, first in high latitudes and then progressively southward to the subtropics. With cooling at the pole during the first months of the Arctic night, low pressure develops in the polar stratosphere and is accompanied by a strong stratospheric jet stream of westerlies at about 70° N. latitude. Generally during the first 3 months of the year, low pressure splits away from the pole to form troughs, and anticyclogenesis occurs in the areas between these troughs. These latter events sometimes take place with a dramatic effect upon stratospheric temperatures. Scherhag [2] was the first to report an abrupt warming under these circumstances. In years following, this phenomenon was investigated by Scrase [3], Wexler [4], Warnecke [5], Lee and Godson [6], and Craig and Hering [7]. Wexler and Moreland [8] ascribed the wintertime "breakdown of essentially zonal flow into large-scale meridional flow" to instability of the stratospheric west winds as they strengthen into a powerful jet stream to balance the increasing meridional temperature gradient during the first months of polar darkness.

A series of six contour and isotherm charts for the 25-mb. surface is presented here to show the breakdown of the polar Low and concomitant stratospheric warming as it transpired in the period following January 17, 1958. The maps showing the significant stages of this breakdown were selected from daily charts for the 50-mb. and 25-mb. surfaces, plotted by the National Weather Analysis Center since June 1957.

Whenever possible the contour analyses of the charts were based on observed data. Unfortunately large areas of sparse data are quite common above the 50-mb. level. This is true even over areas with an adequate station network, for high winds cause balloons to drift out of range and extremely low temperatures lead to premature balloon bursts. In areas where data were scanty, 25-mb. contours were constructed by addition of the 50-mb. contours and the mean thickness of the 50- to 25-mb. layer.

2. DISCUSSION OF CHARTS

The 25-mb. chart of January 17, 1958 (fig. 1) is typical of the pattern that gradually developed after late September 1957, interrupted occasionally by short-period fluctuations. The dominant feature was the broad flow of the Arctic stratospheric jet stream coupled with extremely cold temperatures over the Greenland area. From geostrophic estimation, wind speeds approaching 200 kt. were probable along the jet axis. Over the Aleutians, abnormally high temperatures, associated with a large area of high pressure, became firmly established during the latter part of December. By January 17, some of the warmth had penetrated slowly across Alaska and into central Canada. To show the contrasting stratospheric airmasses, soundings for Bethel, Alaska, to represent the warm air, and Eureka, Canada, the cold air, are reproduced in figure 7. There is a strong similarity between the two soundings below the level of the tropopause, but upward from that point the airmass contrast becomes very pronounced.

By January 24 (fig. 2) a major change had begun to take place. The most noticeable feature was eastward movement of the Aleutian High to a position over the Gulf of Alaska. Cold air persisted over Greenland with an extension southwestward. Colder temperatures than previously observed appeared over the eastern United States. Over central and eastern Canada, the contour and temperature fields had moved into phase.

Four days later on January 28 (fig. 3) a lobe of the cold pocket, that on earlier charts was located over Greenland, had begun to penetrate the Great Lakes area. Examination of intervening charts reveals that horizontal advection does not explain the movement of this cold air pocket. If temperature changes are adiabatic, upwelling of isentropic surfaces is occurring. This is a counterpart phenomenon to the subsidence that permitted temperature rises in spite of very strong horizontal cold air advection over Newfoundland in January 1957, as described by Craig and Hering [7]. South of Greenland, widely scattered reports give evidence of pronounced stratospheric warming, and the −39° C. isotherm can be drawn with reasonable confidence. This is in sharp contrast with temperatures of less than −70° C. that were in that area just 4 days previously. A small area of warming was also developing off the southeastern coast

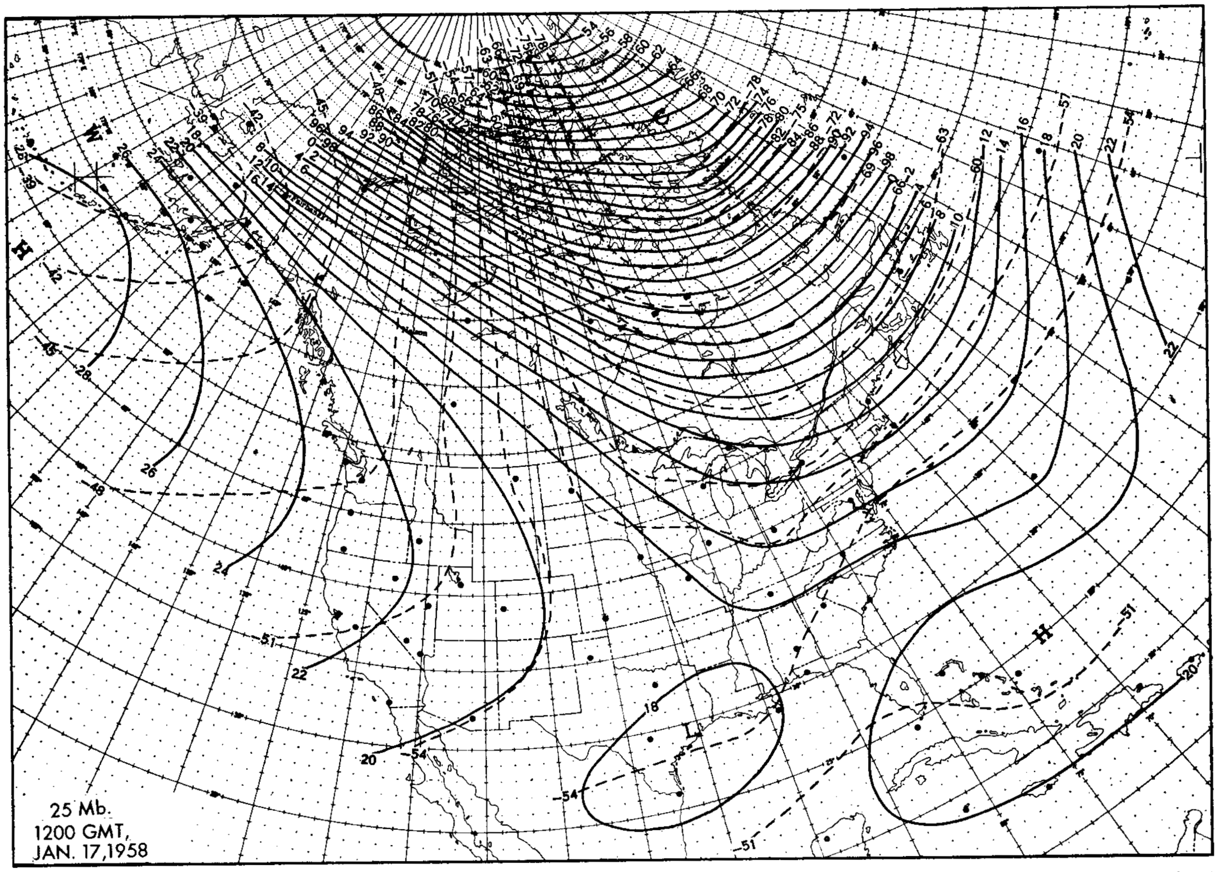

FIGURE 1.—25-mb. chart for 1200 GMT January 17, 1958. Isotherms (dashed lines) are in degrees Celsius. Contours (solid lines) are drawn for 200-ft. height intervals, and labeled in thousands and hundreds of feet. Dots represent stations where data were available at map time or within 12 hours.

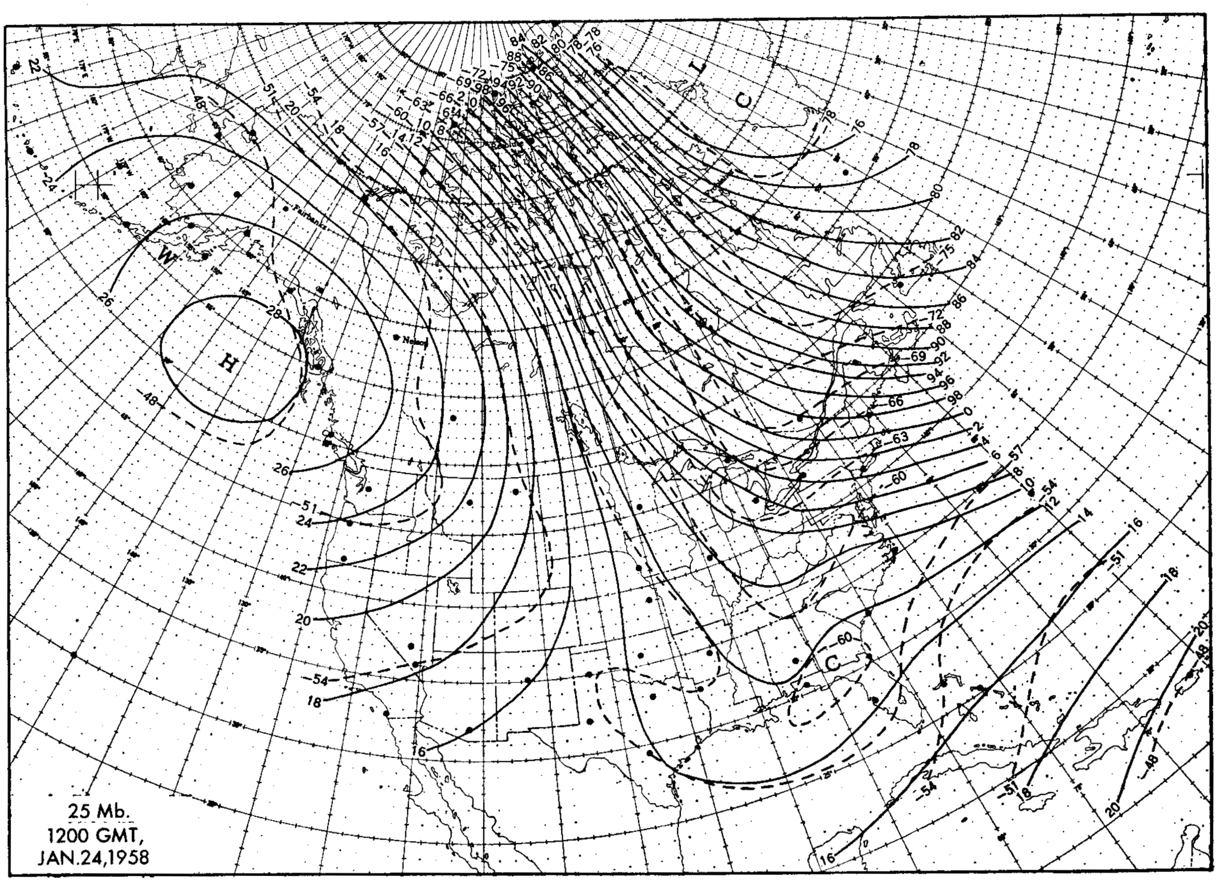

FIGURE 2.—25-mb. chart for January 24, 1958. Isopleths and dots as in figure 1.

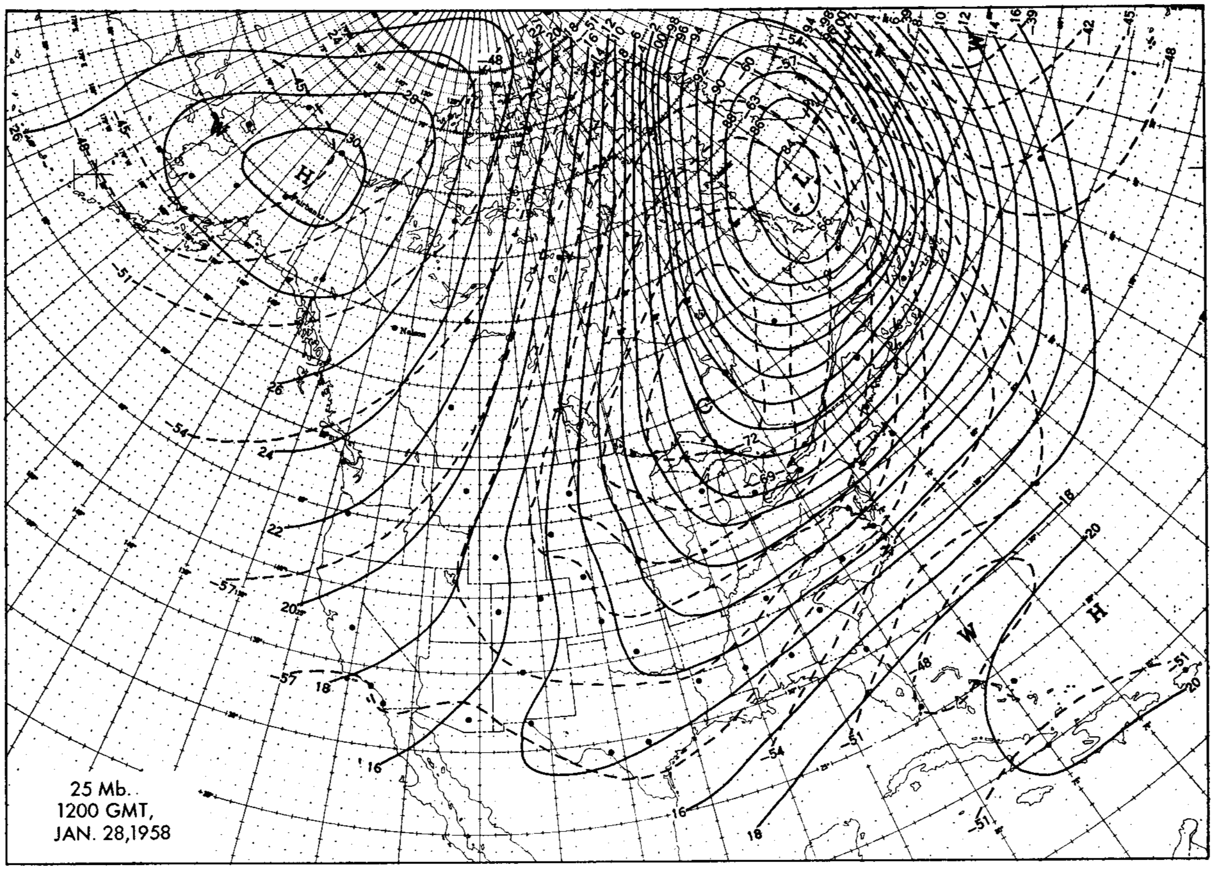

FIGURE 3.—25-mb. chart for January 28, 1958. Isopleths and dots as in figure 1.

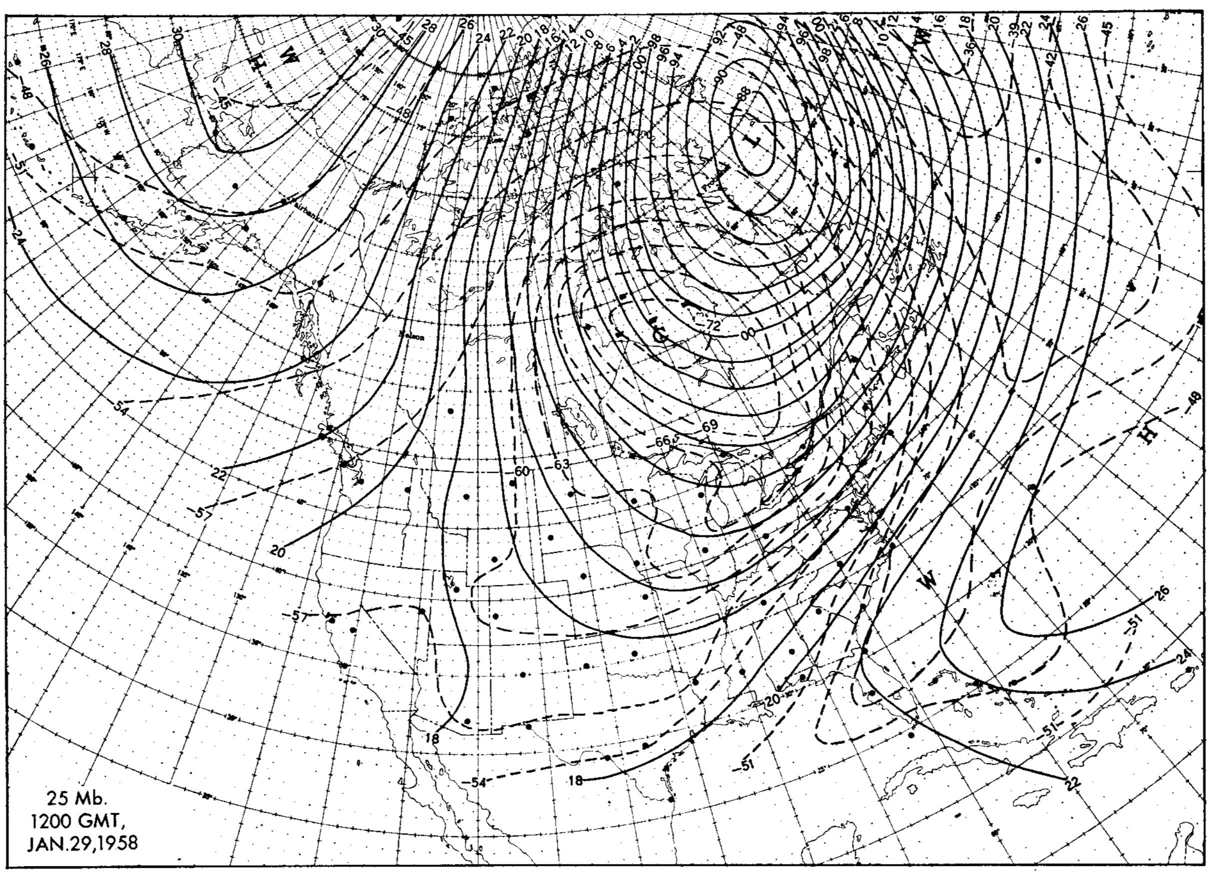

FIGURE 4.—25-mb. chart for January 29, 1958. Isopleths and dots as in figure 1.

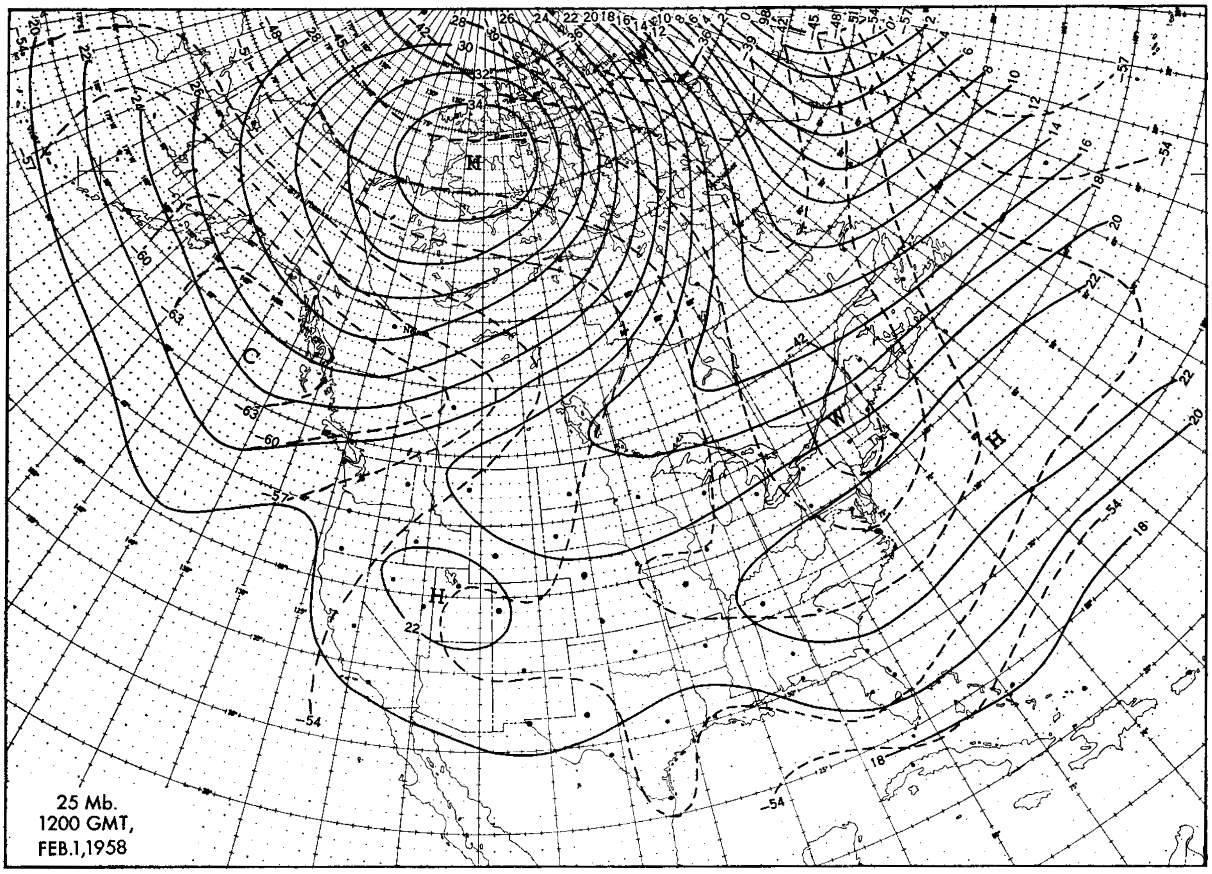

FIGURE 5.—25-mb. chart for February 1, 1958. Isopleths and dots as in figure 1.

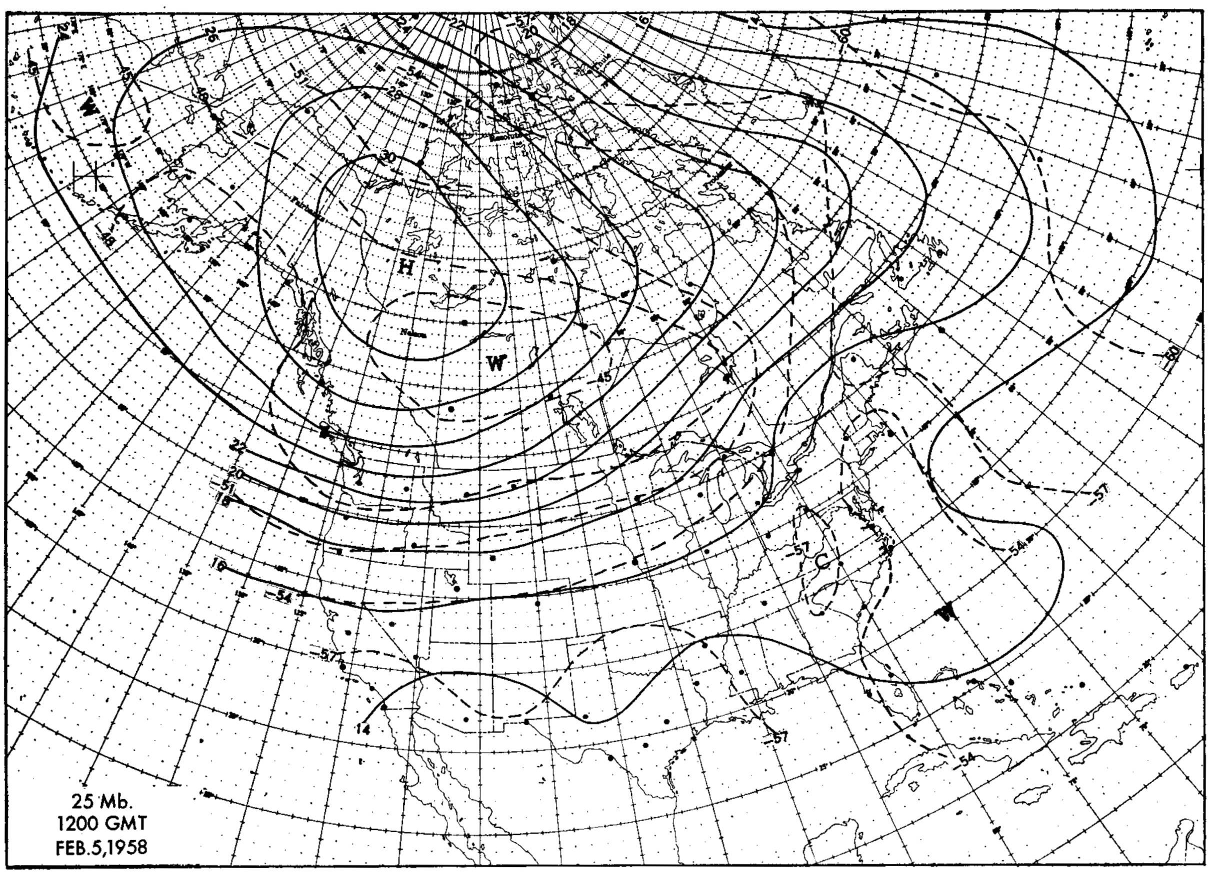

FIGURE 6.—25-mb. chart for February 5, 1958. Isopleths and dots as in figure 1.

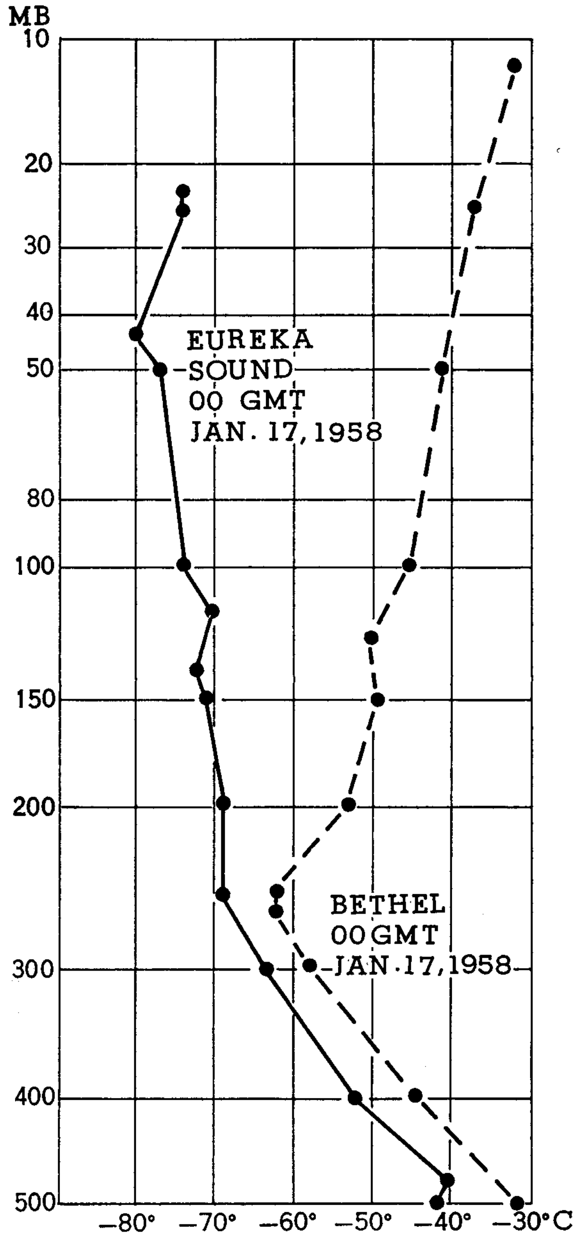

FIGURE 7.—Representative soundings taken in the warm and cold air at beginning of period.

of the United States. This warm area may already have been connected with the one south of Greenland, as it was in later charts, but scarcity of data over the Atlantic makes this uncertain. The association of stratospheric anticyclogenesis and warming with increase of total ozone content has been discussed in detail by Wexler [9]. The phenomenon is vividly illustrated in this case by total ozone content of 0.48 cm. and 0.49 cm. measured with the moon as light source at Alert and Resolute at about the time of figure 5. These provisional values, furnished through the courtesy of the Canadian Meteorological Service, represent increases of 0.25 cm. and 0.13 cm. from the immediately previous measurements made 4 weeks earlier. In the computations, use was made of the Vigroux absorption coefficients, which give ozone values about 36.5 percent larger than those given by the older Ny and Choong coefficients.

FIGURE 8.—1200 GMT temperatures at 25 mb. over Washington, D. C., from January 17, 1958 to February 5, 1958. Circles show estimated temperatures.

By January 29 (fig. 4), the cold air pocket at 25 mb. was centered over Hudson Bay slowly shrinking in size obviously as a result of subsidence. This conclusion is also indicated by 50-mb. charts where, on the same dates, the cold pocket was displaced to the northeast of its position at 25 mb. The lowest observed temperature was at least 6 C.° higher on January 29 than 5 days earlier. Stratospheric warming was well established (fig. 4) with a maximum somewhere east of Greenland and a warm tongue extending southwestward across Florida. The highest 25-mb. temperature noted from available data was −19° C. at Keflavik, Iceland (off the map). The warm air located just off the southeastern United States coast in figure 4 seems to have originated in the eastern Caribbean area. While moving northward, it had intensified and was about to merge with the main body of warm air to the north. At 1800 GMT of January 29, a temperature of −27° C. was observed at the 8-mb. surface (about 106,000 ft.) above Washington, D. C. during one of a series of special soundings released from Andrews Air Force Base. This observation is interesting because it indicates the degree of vertical slope of the warm air (at 13 mb., or about 96,000 ft., the temperature at both Hatteras and Washington was −44° C.). At 25 mb., the temperature at Washington (fig. 8) was already rising rapidly, from −65° C. on January 27 to −43° on January 31.

On the 25-mb. chart for February 1 (fig. 5), the cold pocket had drifted with some modification to the Gulf of Alaska. The 25-mb. contour and isotherm patterns were then in striking contrast to those of January 17. Warm air covered Greenland and extended southwestward into the eastern United States. In southern Alaska, temperatures were nearly 20 C.° lower than before. As the great anticyclone drifted into northwestern Canada, the polar

Low moved southward and then eastward but with a trough extending across southern Canada. Over the southern two-thirds of the North American continent on February 5 (fig. 6), easterly flow had become established in a temperature field indicating increase of wind speed with height.

3. CONCLUDING REMARKS

The manner in which the polar night stratospheric jet stream and its associated cold core annually drift away from the pole and lose strength has only recently become observable through increasing amounts of data at 25 mb. and above. Although each year the breakup tends to occur on a different date and in a different region, it is usually accompanied by a spectacular sequence of events. The sequence of events in 1958, as illustrated here, differed strikingly from that of 1957 when the cold air entered the United States through western Canada just prior to the appearance of "explosive" warming 25 mb. over Newfoundland. The abnormally warm air then moved northward across Greenland. In March 1956, warming moved into central and southern Canada from the Alaskan region but was not accompanied by a rapid breakdown of the circumpolar Low. Other cases studied, dating back to 1948, show a variety of breakup times and magnitudes of stratospheric warming.

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